Modeling Framework and Results to Inform Charging Infrastructure Investments

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June 13, 2019

DOE Vehicle Technologies Office
2019 Annual Merit Review and Peer Evaluation Meeting

Project ID VAN026

Overview

Timeline

- Project start date: October 1, 2015
- Project end date: September 30, 2019
- Percent complete: 85% complete

Budget

- Total project funding
  - DOE share: $1,700k
    - Includes $325k to INL
  - Contractor share: NA
- Funding for FY 2016: $150k
- Funding for FY 2017: $800k
- Funding for FY 2018: $250k
- Funding for FY 2019: $500k

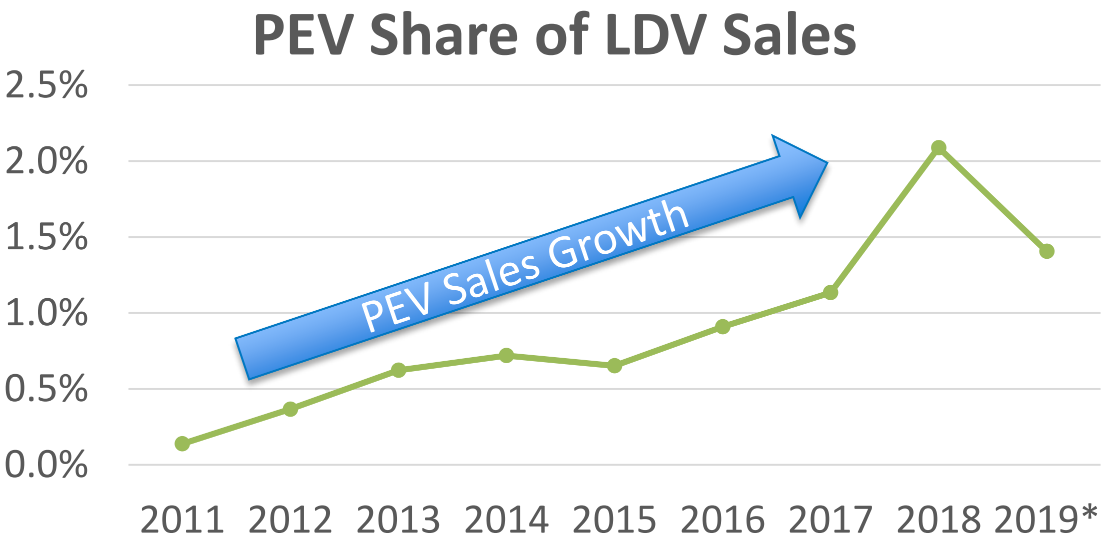
Barriers

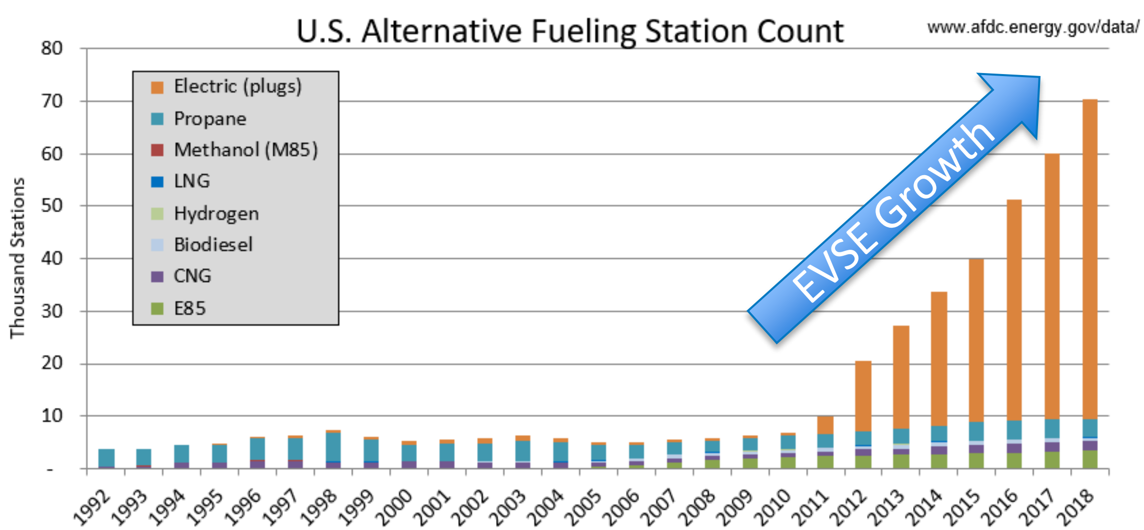
- Availability of alternative fuels and electric charging station infrastructure
- Consumer reluctance to purchase new technologies
- Maintenance of local coalition effectiveness

Partners

- Idaho National Laboratory (INL)
- California Energy Commission
- Electric Power Research Institute (EPRI)
- U.S. Department of Transportation
- U.S. Environmental Protection Agency
- U.S. DOE SMART Mobility Consortium
- Others listed by project in slides

Significant Public/Private Investments Being Made in EVs & Charging Infrastructure





Disparate group of stakeholders require consistent approach for intelligently informing infrastructure investments to grow the PEV market and improve domestic energy security**

*Partial-year sales percentage

**Automotive manufacturers, electric utilities, charging networks, transportation network companies, state/local governments

CNG: compressed natural gas
EVSE: electric vehicle supply equipment
LDV: light-duty vehicle
LNG: liquid natural gas
PEV: plug-in electric vehicle

Nine Analysis Projects Contribute to the Overall Research Goal

Milestones

***Completed**
****On-going**

How much charging infrastructure is needed at a city/state level?
1. Massachusetts Case Study*
2. Columbus Scenario Analysis*

How do infrastructure needs scale nationally?
3. National Infrastructure Analysis*
4. PEV Infrastructure Tool*

How accessible is residential charging?
5. Residential Access to PEV Charging**

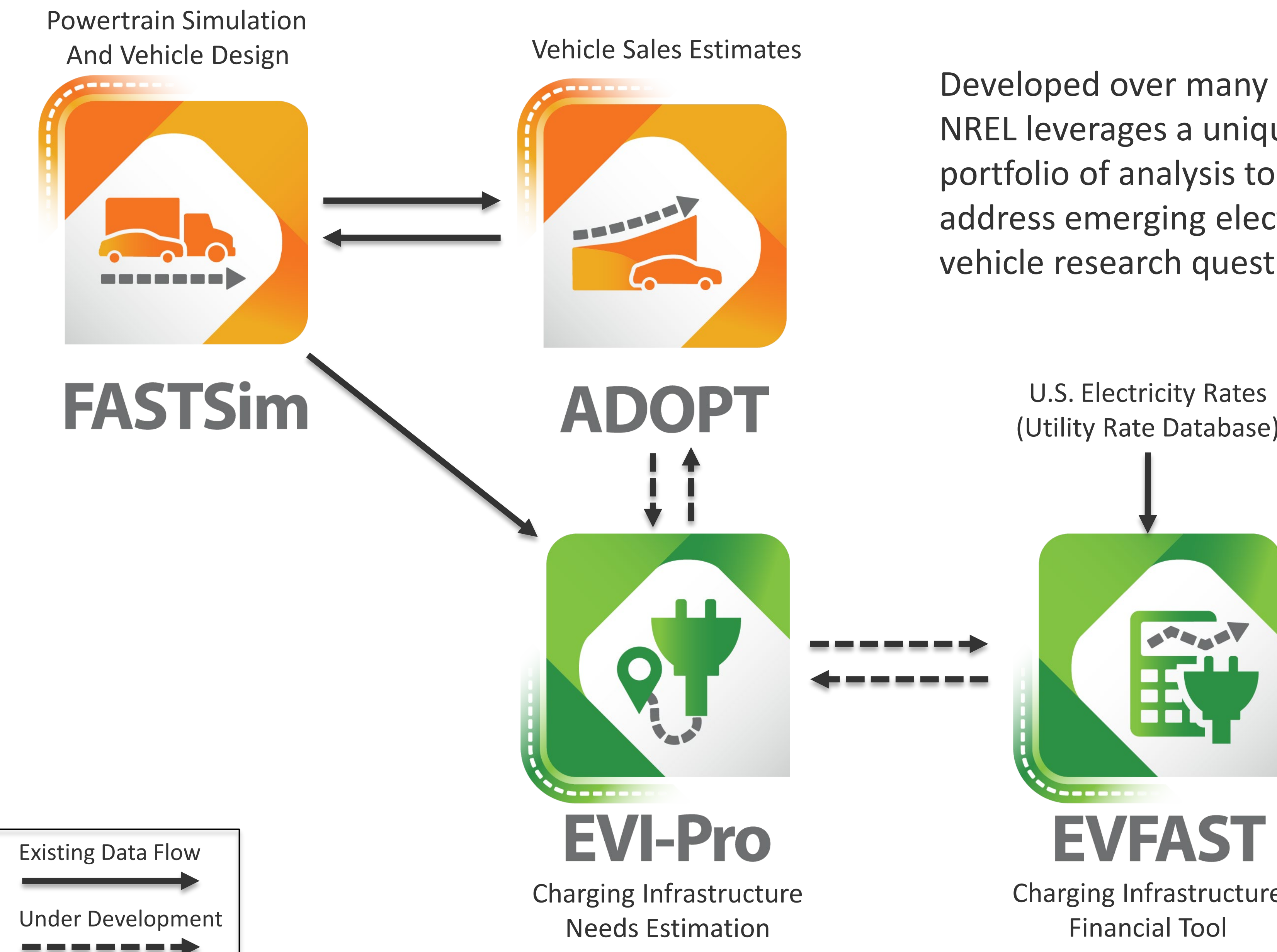
What is the levelized cost of electricity for PEV charging?
6. Demand Charge Impacts (w/INL)*
7. Financial Analysis (E-FAST) (w/INL)**

How might VTO investments and infrastructure availability affect the PEV market?
8. VTO Benefits Timing Analysis**
9. Future of Infrastructure Benefits Analysis**

Each project draws upon similar core analytic methods & data

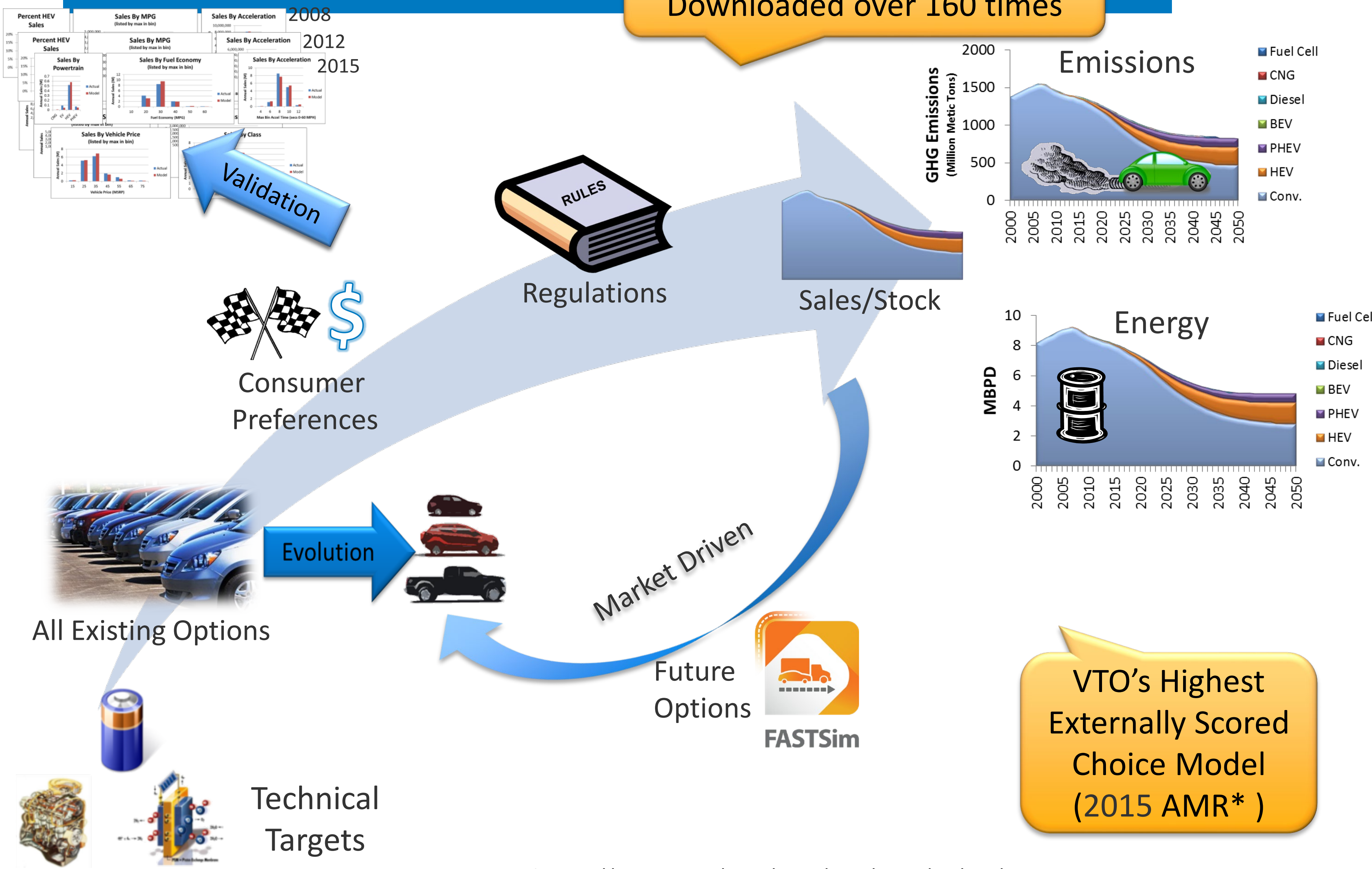
NREL Core Analytic Methods & Data

Developed over many years, NREL leverages a unique portfolio of analysis tools to address emerging electric vehicle research questions



ADOPT Overview

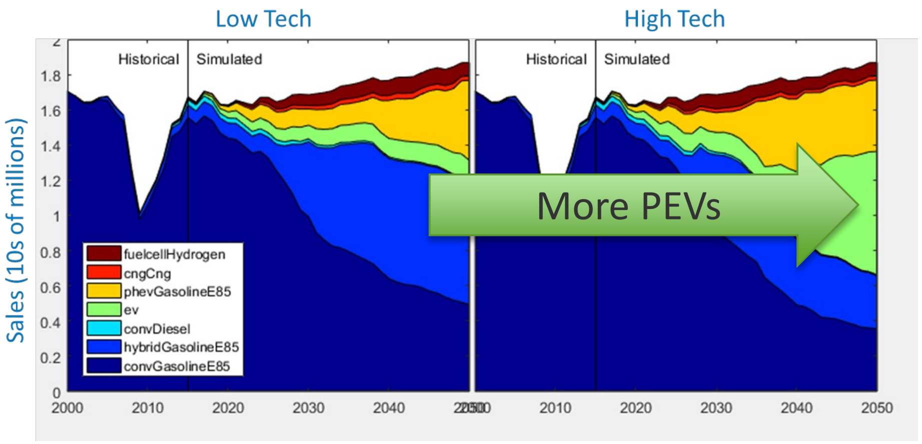
Publicly available
Downloaded over 160 times



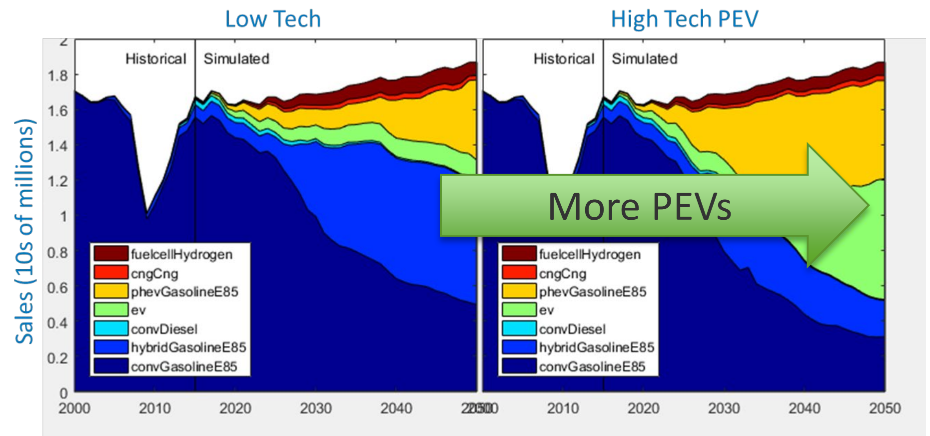
*https://energy.gov/sites/prod/files/2015/12/f27/09%20-%20Vehicle%20Analysis.pdf

VTO Benefits Timing Analysis

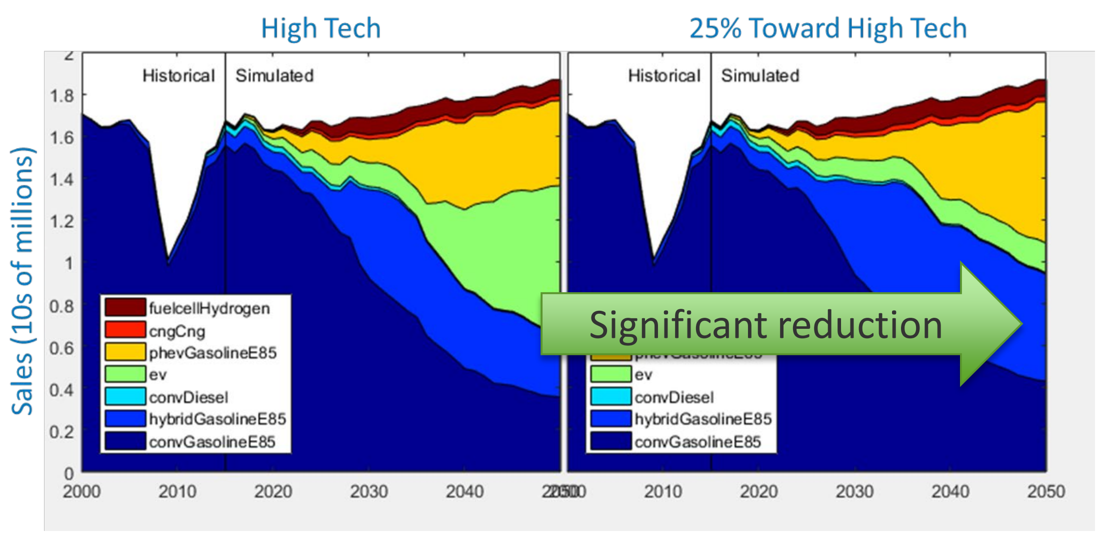
Meeting all VTO targets on time

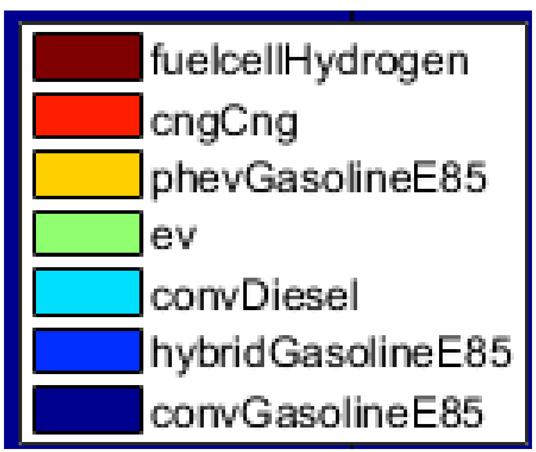


Meeting PEV-related targets



Slower tech improvement

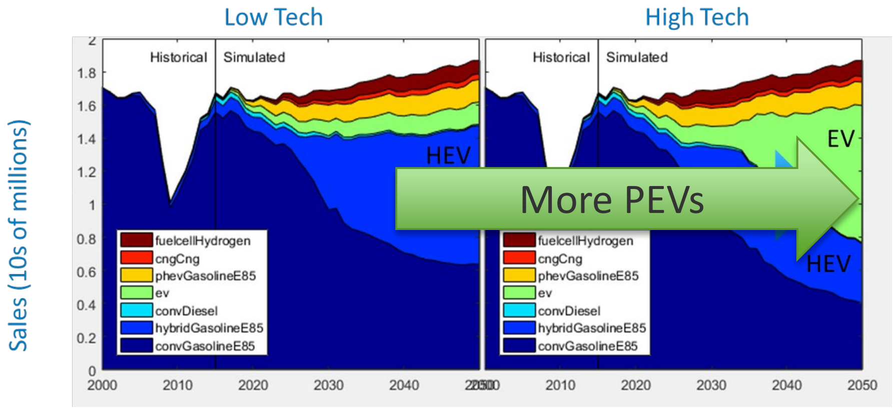




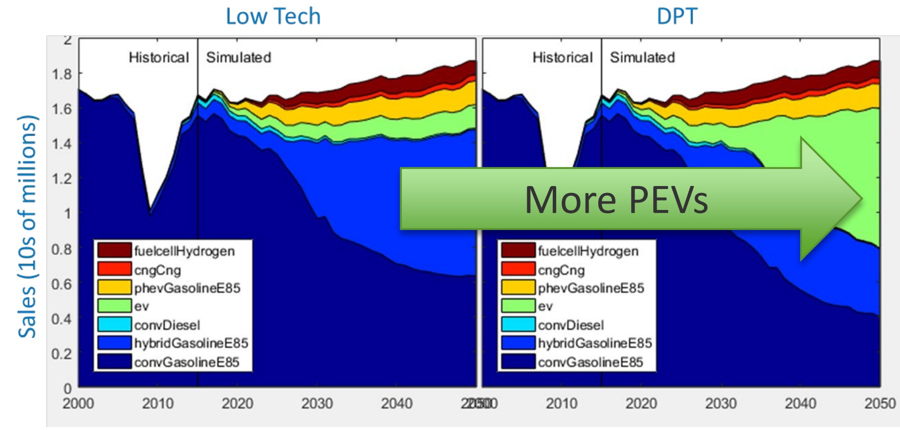
Future of Charging Infrastructure Benefits Analysis

Accomplishments 2

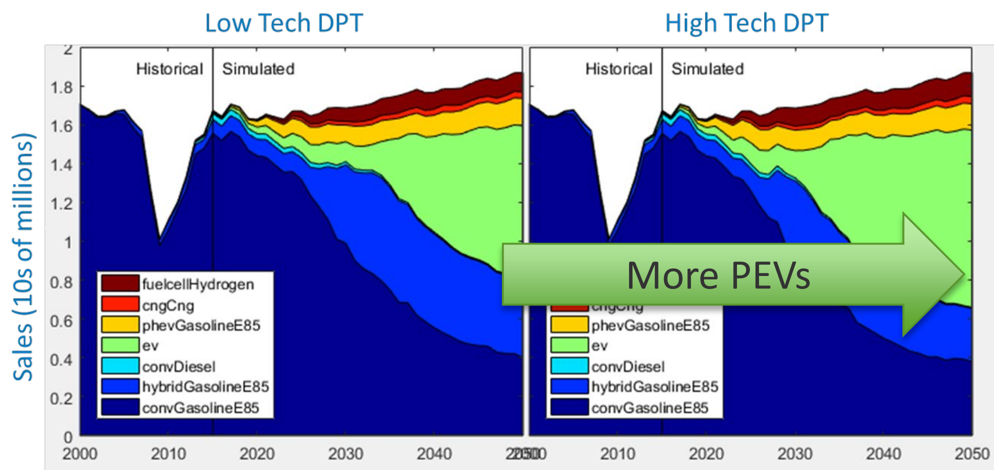
Meeting all VTO targets on time

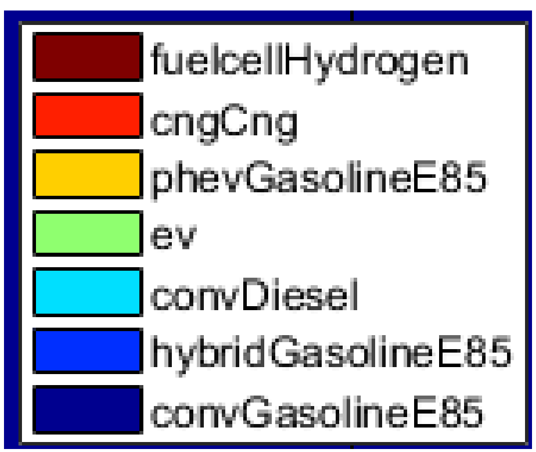


Dynamic power transfer on interstates



Doing both





Financial Analysis of PEV Charging (E-FAST) (w/INL)

Most studies assume that average residential electricity pricing applies to all PEV charging.

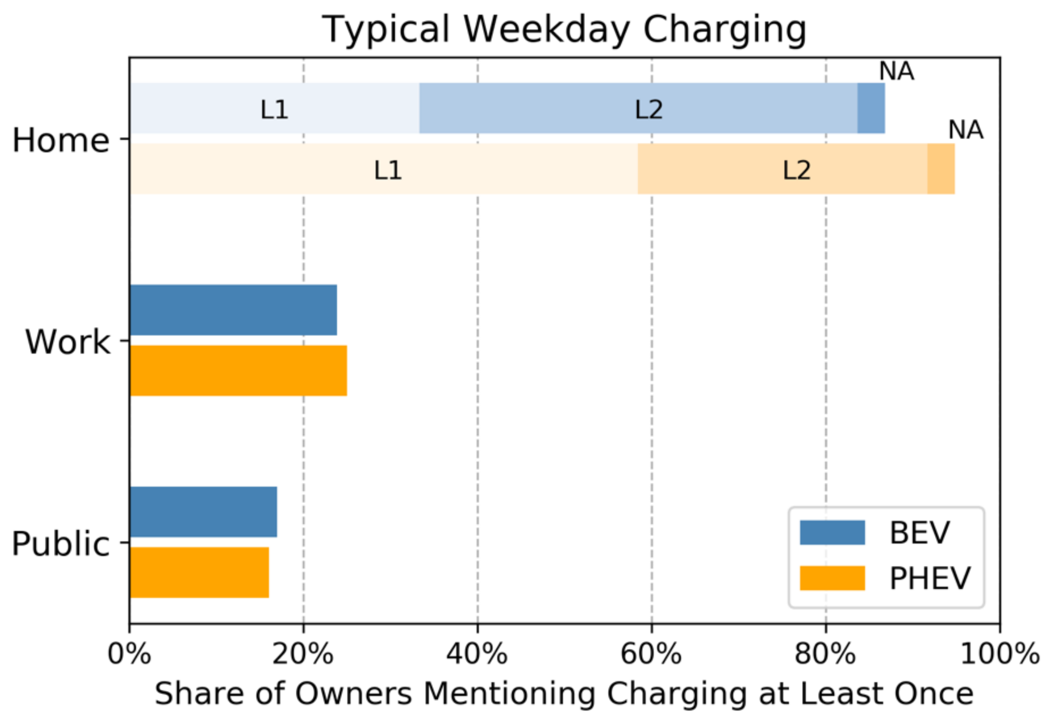
However, PEVs can be charged in different ways, and e**lectricity cost** varies greatly based on:

- Power level
- Location (home, workplace, public)
- Load shapes (e.g., impact of demand charges)
- Time-of-day (TOU) rates

Weight different charging options to compute scenarios of PEV levelized "fuel cost" for different scenarios

- Residential
- Workplace
- Public DC Fast charging

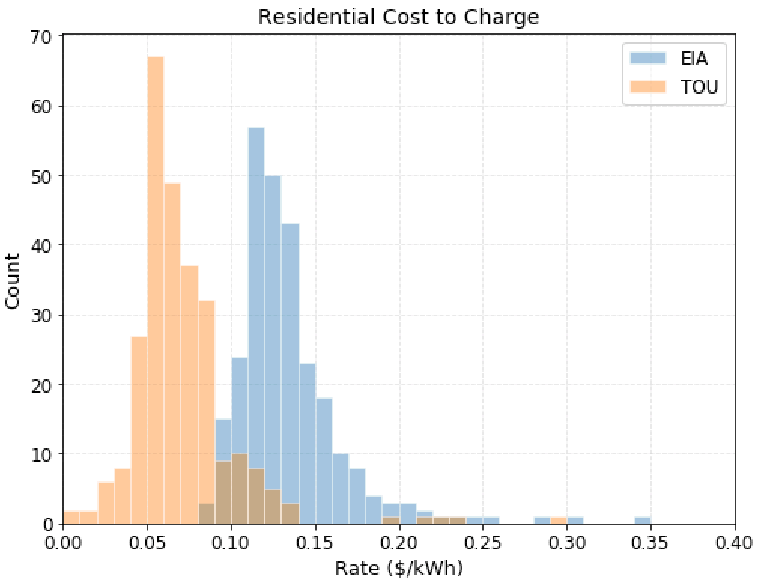
Account for equipment, installation, and grid-purchased electricity

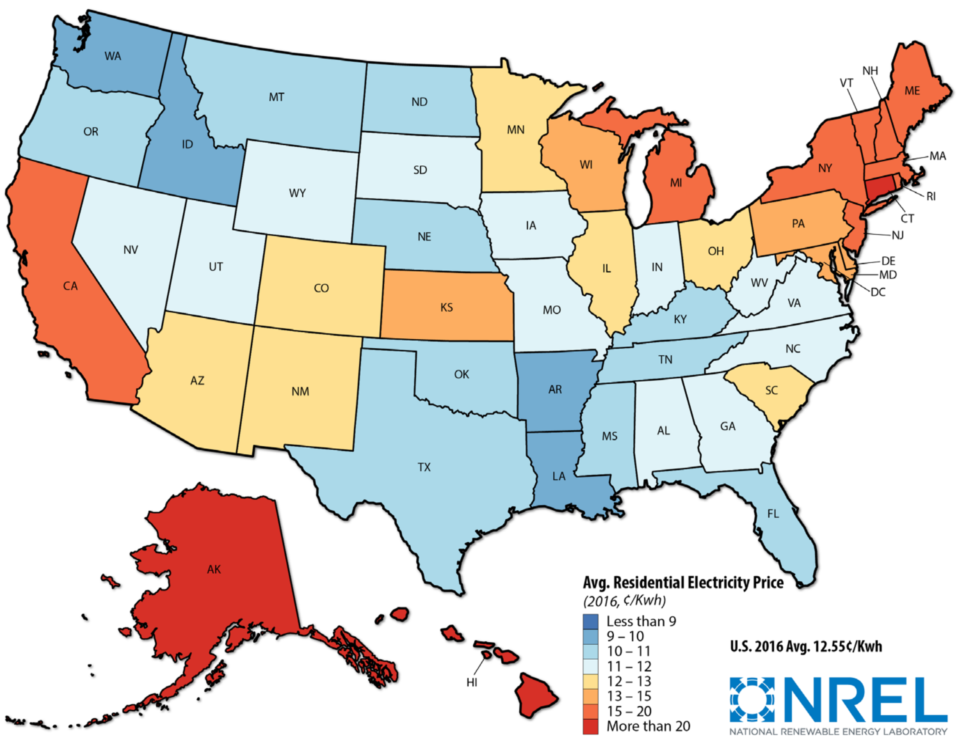


Financial Analysis of PEV Charging (E-FAST) (w/ INL)

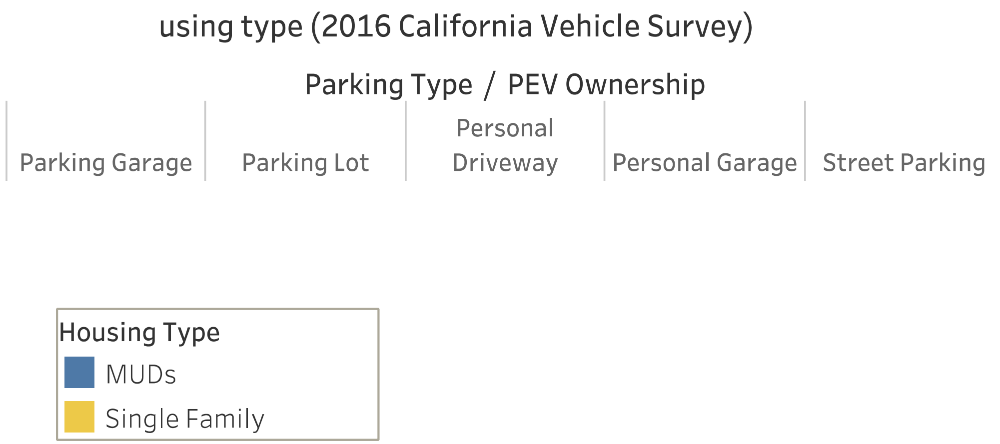
NREL analysis indicates significant regional variation in residential electricity prices for PEV charging.

Further, service territories offering TOU rates for overnight charging can significantly reduce cost of residential charging.





Residential Access to PEV Charging



Approach

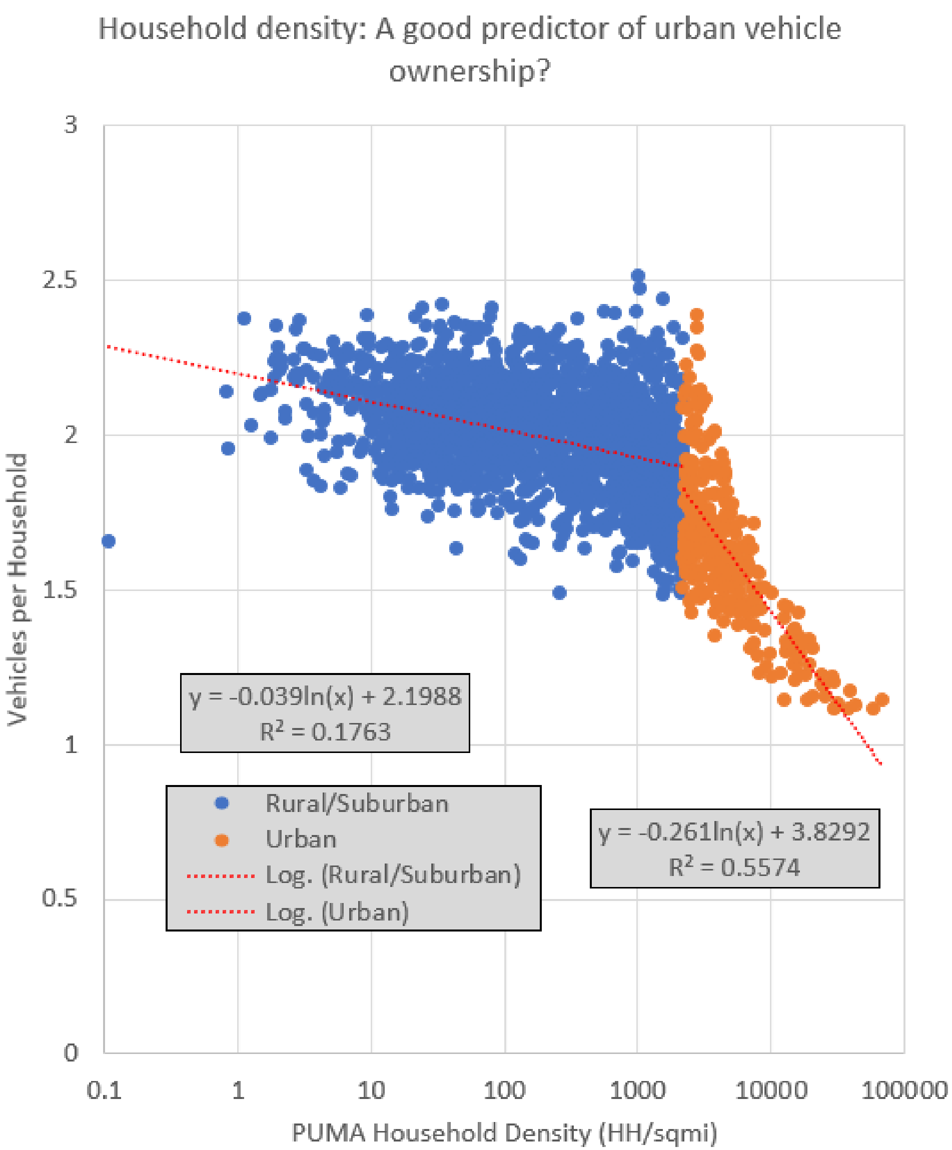
Analyze 2016 California Vehicle Survey data for correlations between PEV ownership, residence type, and residential parking type.

Significance

Present-day PEV ownership in CA dominated by individuals with likely access to residential charging (residents of single family dwellings with access to off-street parking).

MUD: multi-unit dwelling

Residential Access to PEV Charging



Approach

NREL has organized national housing data from U.S. Census Public-Use Microdata Samples (PUMS) database to estimate the potential for various household types to consistently overnight charge PEVs.

Significance

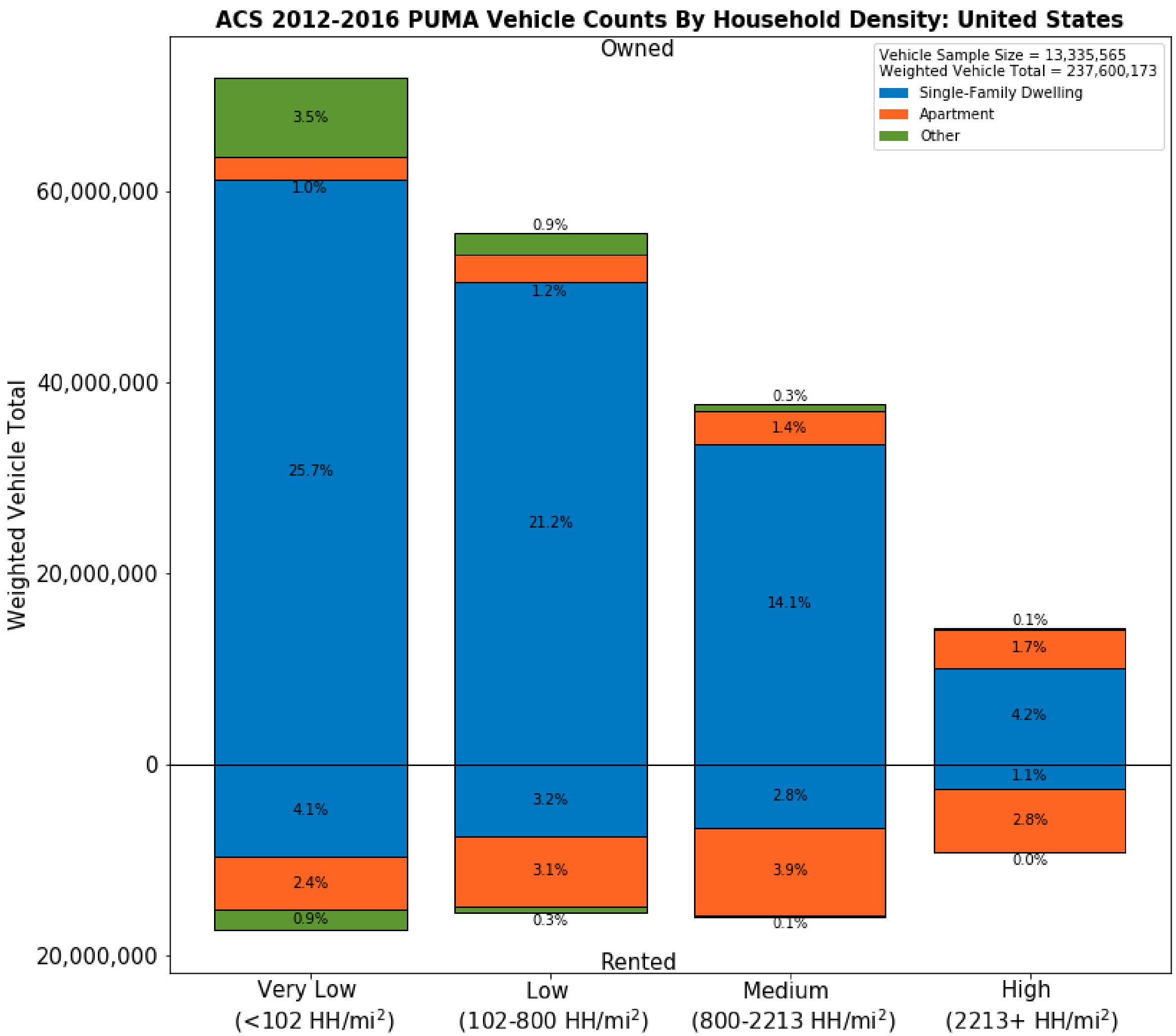
Apartments are estimated to make up 27% of national housing stock, but only represent 17% of national LDV stock as vehicle ownership is shown to decrease with housing density.

HH: household

Residential Access to PEV Charging

Estimate of U.S. LDV stock by:

- Housing density, residence type, and tenure



Analysis Highlights

- 25% of LDV stock is owned by renters
- 17% of LDV stock is owned by residents of apartments
- 10% of LDV stock is owned by residents of high density neighborhoods

Significance

These subpopulations may not have ability to install residential charging and/or may not have a consistent location to park their vehicle for overnight charging.

Property Owners

Property Renters

Responses to Previous Year Reviewers' Comments

Comment Response

- FY18 reviewers commented that estimation of public charging infrastructure requirements (using EVI-Pro) should consider needs of MUD residents, transportation network companies (TNCs), and commercial vehicle operators.

  – **Charging at MUDs**: VTO and NREL are addressing residential charging infrastructure needs of MUD residents as part of the FY19 analysis.

  – **Electrification of TNCs**: Charging infrastructure needs of TNC operators is being led by VTO EEMS program through SMART AFI Pillar.

  – **Commercial Vehicles:** VTO and /NREL, in collaboration with Tesla, have recently initiated a study of charging infrastructure and grid impacts of Class 8 semis. Analysis of additional medium- and heavy-duty (MD/HD) vocations remains an area of interest.

Collaboration and Coordination with Other Institutions

The following stakeholder groups contributed to each project listed below.

California Energy Commission – Collaborative development of EVI-Pro

Massachusetts EVSE Case Study

- Massachusetts Executive Office of Energy and Environmental Affairs, California Energy Commission, EPRI

Columbus PEV Infrastructure Scenario Analysis

- City of Columbus, Ohio State University, U.S. Department of Transportation, MORPC, Clean Fuels Ohio, Ohio EPA, AEP, Honda, ChargePoint, GDP Group, HNTB

National Corridor/Community EVSE Analysis

- U.S. Department of Transportation, U.S. Environmental Protection Agency, ElectrifyAmerica, Ford, GM, Tesla, EPRI, Sacramento Municipal Utility District (SMUD), Atlas Public Policy, California Energy Commission, City and County of Denver, Georgetown Climate Center, University of California - Davis, University of Washington, ICCT, Northeast States for Coordinated Air Use Management (NESCAUM)

PEV Infrastructure Tool (EVI-Pro Lite)

- ChargePoint, City and County of Denver, North Central Regional Clean Cities Coordinators, Clean Cities West Virginia, Colorado Electric Vehicle Coalition, Edison Electric Institute (EEI), Electrification Coalition, GM, Maryland Public Service Commission, Massachusetts Office of Energy & Environmental Affairs, MJ Bradley, New York Power Authority, Sierra Club, Southern Company, Tesla, U.S. Environmental Protection Agency

Collaboration and Coordination with Other Institutions

Collaboration 2

Cost of DC Fast Charging and Demand Charges

- AeroVironment
- Ameren Missouri
- American Public Power Association (APPA)
- Atlas Public Policy
- ChargePoint
- Colorado Energy Office
- EEI
- Electric Drive Transportation Association
- EPRI
- Electrify America
- Energetics Incorporated
- EVgo
- Exelon
- Ford Motor Company
- Georgia Power
- Georgia Public Service Commission
- Greenlots
- Missouri Public Service Commission
- National Association of Regulatory Utility Commissioners (NARUC)
- National Association of State Energy Officials (NASEO)
- National Rural Electric Cooperative Association (NRECA)
- National Rural Utilities Cooperative Finance Corporation
- Nissan North America
- NESCAUM
- NV Energy
- PacifiCorp
- Portland General Electric
- Rappahannock Electric Cooperative
- SMUD
- SemaConnect Inc.
- U.S. Department of Energy
- U.S. Department of Transportation
- U.S. Environmental Protection Agency
- Washington State Department of Commerce

Remaining Challenges and Barriers

- **Evolving consumer charging behavior preferences:**
  - Need to understand evolving consumer preferences as PEVs enter new consumer segments (MUDs) and new technology enters the market (high-power fast charging, longer-range EVs). Potentially mitigated via real-world data collection (surveys, vehicle/charging station data collection).

- **Uncertainty regarding interplay between LD and MD/HD infrastructure:**
  - EV charging infrastructure can be a significant capital investment that could benefit from dual utilization across LDV and MD/HD segments. Vehicle needs and interoperability of charging infrastructure for these segments remain uncertain.

- **Urbanization and new mobility options:**
  - Future sales estimates and infrastructure projections rely heavily on existing trends for calibration and data inputs. Changing housing and vehicle ownership preferences could impact projections in unforeseen ways, prompting a need for on-going sensitivity/uncertainly analysis.

Proposed Future Work

NREL Led:

- Charging Behavior and Grid Impact of Electrified Class 8 Semis
  - In collaboration with Tesla and TBD electric utility
- Micro-Mobility Energy Opportunities
- MD/HD Benefits Analysis

NREL Support:

- Minimum Viable Modeling for State/Regional/National Analysis
  - Lead by INL
- Multi-Lab Total Cost of Ownership Analysis
  - Lead by ANL

Any proposed future work is subject to change based on funding levels

Summary

Relevance

- Significant investments are currently being made in PEV charging infrastructure

Approach

- Nine distinct projects contribute to the overall research goal
- ADOPT estimates LDV sales relative to technology progress scenarios
- NREL/INL are utilizing best available data to estimate cost of and access to PEV charging

Technical Accomplishments and Progress

- Meeting all VTO targets on time has a significant impact on PEV sales, energy consumption, and emissions
- Implementing DPT on interstates provides another pathway to vehicle electrification
- NREL/INL have developed rigorous methods to calculate cost of PEV charging
- Analysis of LDV stock by housing/parking to estimate residential charging access

Collaboration

- Multiple stakeholder groups have contributed to each of the different projects

Proposed Future Research (subject to future funding)

- Micro-mobility and MD/HD charging & benefits analysis

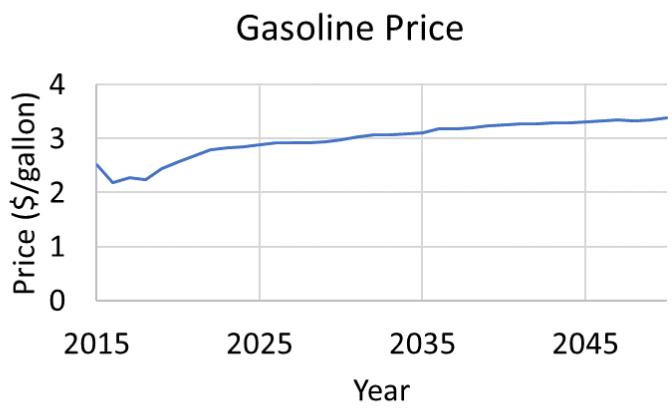
Thanks! Questions?

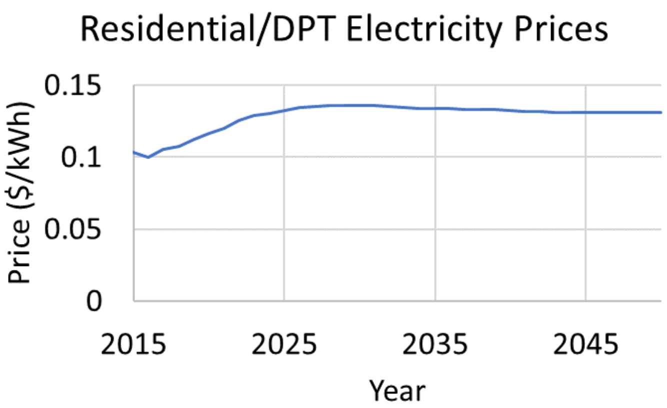
This work was funded by the US Department of Energy Vehicle Technologies Office.

Technical Back-Up Slides

ADOPT Assumptions

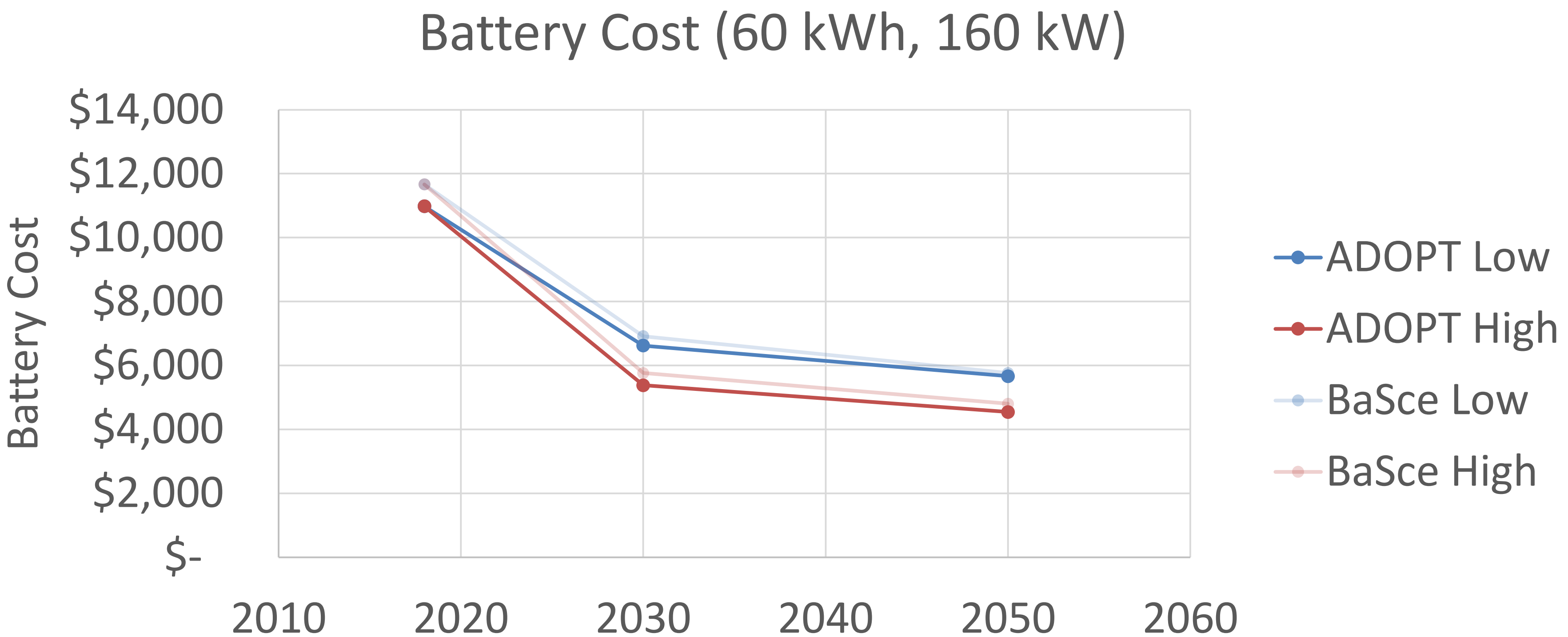
- Fuel prices: Annual Energy Outlook (AEO) 2017 reference oil prices





- 2050 electricity emission: 30% reduction
- Technologically and economically “feasible” regulations
- Consistent with BaSce 2017 technical targets
- Plug-in hybrid electric vehicle (PHEV) acceleration specification equals average with and without internal combustion engine
- DPT increases
  - Perceived battery EV range by 3 times the battery range
  - Vehicle price $53/kW

Technical Targets Highlights: Batteries



Low Tech	2018	2030	2050
$/kW	$36	$23	$20
$/kWh	$82	$44	$36
Constant	$300	$300	$300

High Tech	2018	2030	2050
$/kW	$36	$18	$15
$/kWh	$82	$36	$30
Constant	$300	$300	$300

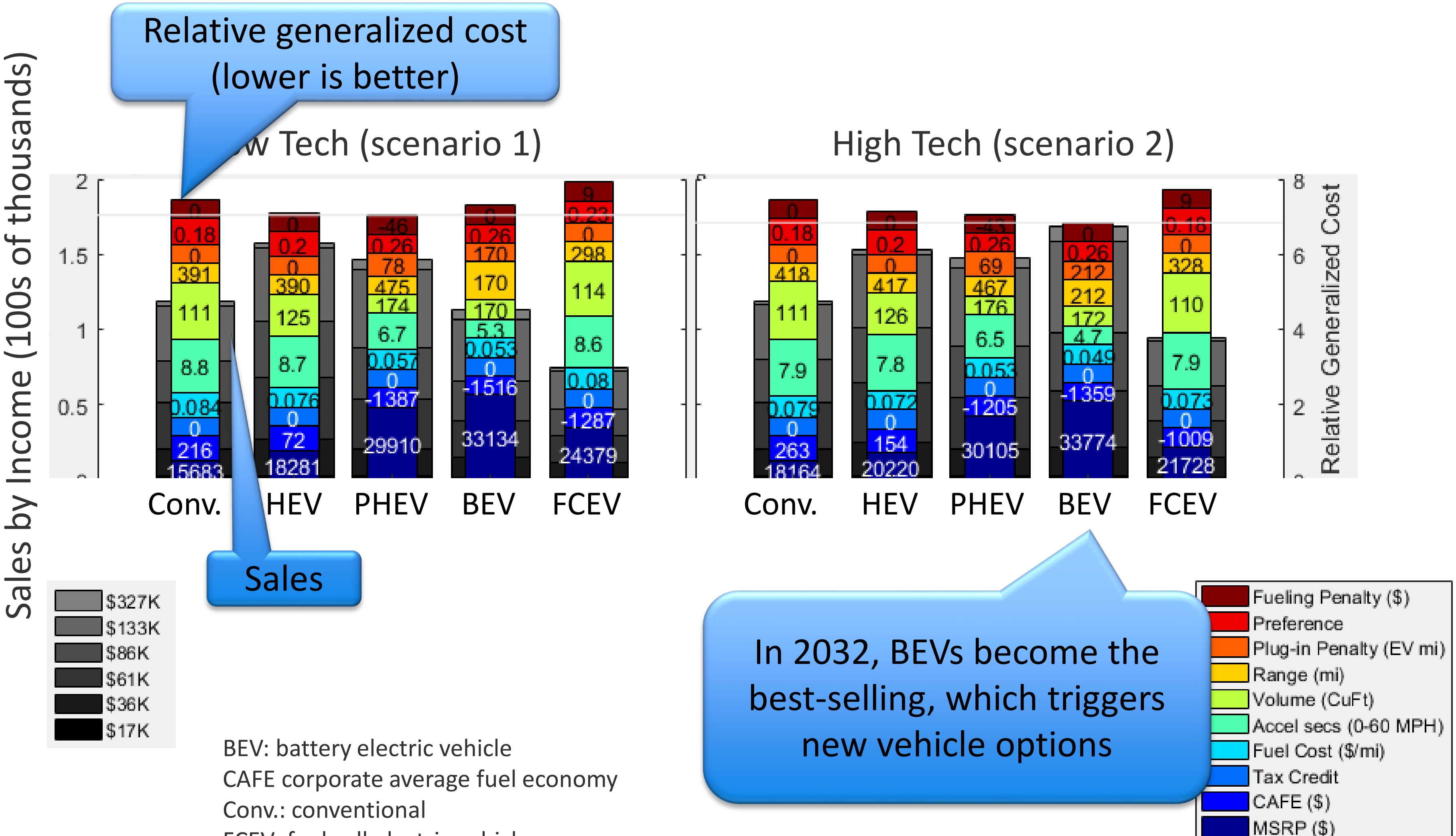
Technical Targets Highlights: Other

Low Tech	2018	2030	2050
Motor ($/kW)	$18	$10	$6.3
Glider Mass Reduction	4%	9%	19%
SI Peak Efficiency	37%	38%	43%
Atkinson Peak Efficiency	40%	40%	42%

High Tech	2018	2030	2050
Motor ($/kW)	$17	$6.2	$4
Glider Mass Reduction	11%	29%	42%
SI Peak Efficiency	40%	43%	50%
Atkinson Peak Efficiency	40%	46%	52%

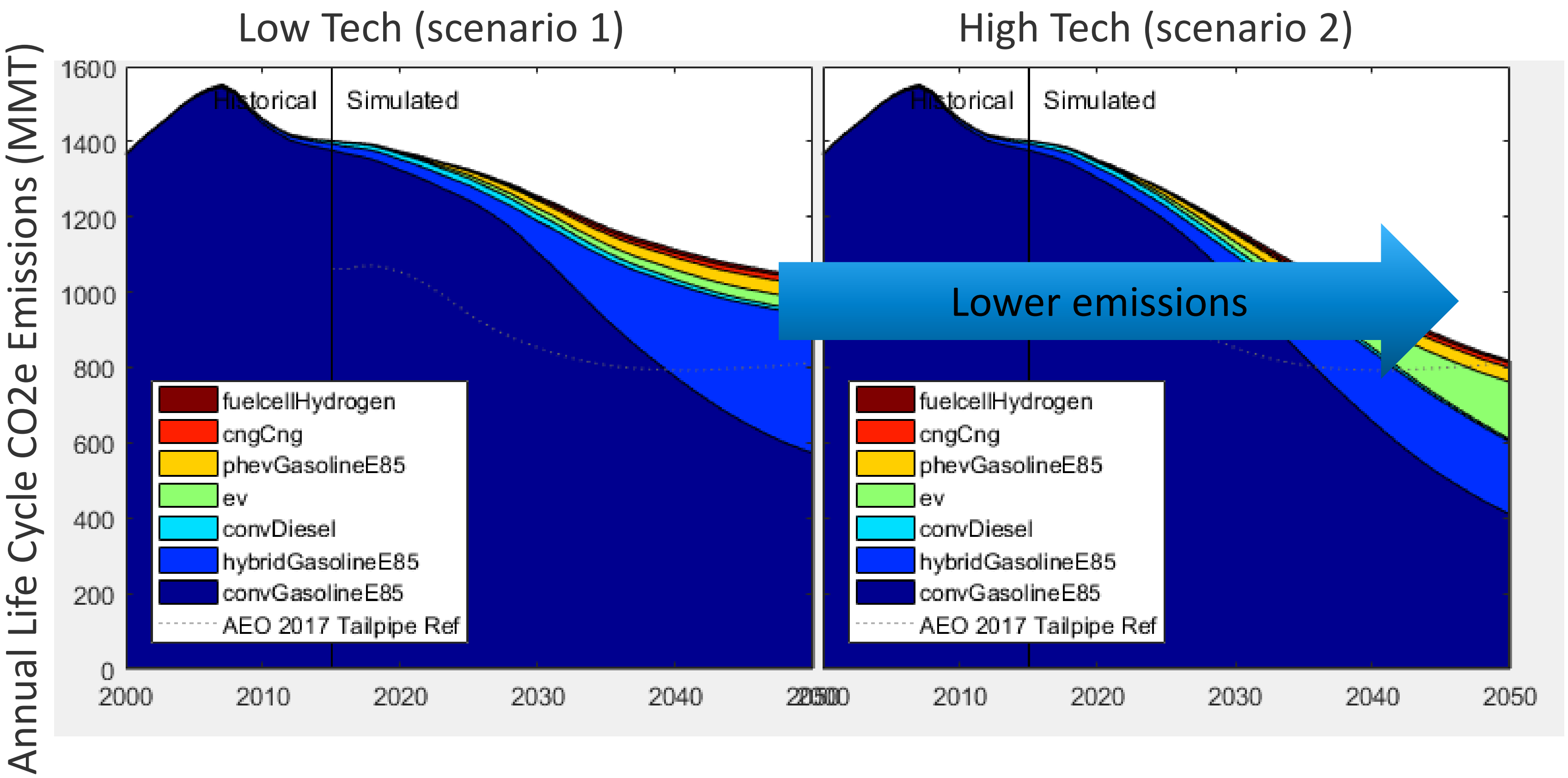
SI: spark ignition

Baseline Results Explanation (DPT Analysis)



BEV: battery electric vehicle
CAFE corporate average fuel economy
Conv.: conventional
FCEV: fuel cell electric vehicle
MSRP: manufacturers suggested retail price

Baseline Results (DPT Analysis): Emissions



CO2e: carbon dioxide equivalent
MMT: million metric tonnes